Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

THE "TURTLE-OREODON LAYER" OR "RED LAYER," A CONTRIBUTION TO THE STRATIGRAPHY OF THE WHITE RIVER OLIGOCENE (RESULTS OF THE PRINCETON UNIVERSITY 1920 EXPEDITION TO SOUTH DAKOTA).

(PLATE VII.)

INVESTIGATION AIDED BY A GRANT FROM THE MARSH FUND OF THE NATIONAL ACADEMY OF SCIENCES.

BY WILLIAM J. SINCLAIR.

(*Read April 22, 1921.*)

Perhaps the most abundantly fossiliferous horizon in the White River Oligocene badlands of South Dakota is a nodular clay band at the base of the Brule formation (Oreodon beds), which, from the abundant remains of turtles and oreodons, the rusty color of the fossils in general, and the pinkish-gray tone of the matrix, has long been known to collectors as the "turtle-oreodon layer" or "red layer." It is remarkably persistent throughout a region miles in extent and, although known and collected from for the past seventy years, is still a never-failing source of splendidly preserved material. In thickness it varies considerably, values ranging from 29.5 to 39 feet having been obtained within a few miles of each other in Pennington County in the Big Badlands, where the "red layer" is most typically developed, and of 43 feet at Cedar Pass near Interior in Jackson County. There is considerable facial difference between these two areas, necessitating their separate description.

In the Big Badlands, throughout the basins of Indian Creek, Spring Creek, Bear Creek, Jones Creek and Cain Creek, in Pennington County, the base of the "turtle-oreodon layer" lies immediately above a white more or less completely silicified limestone in discontinuous lenses, forming, wherever present, excellent horizon markers. From analogy with a similar material found in the middle

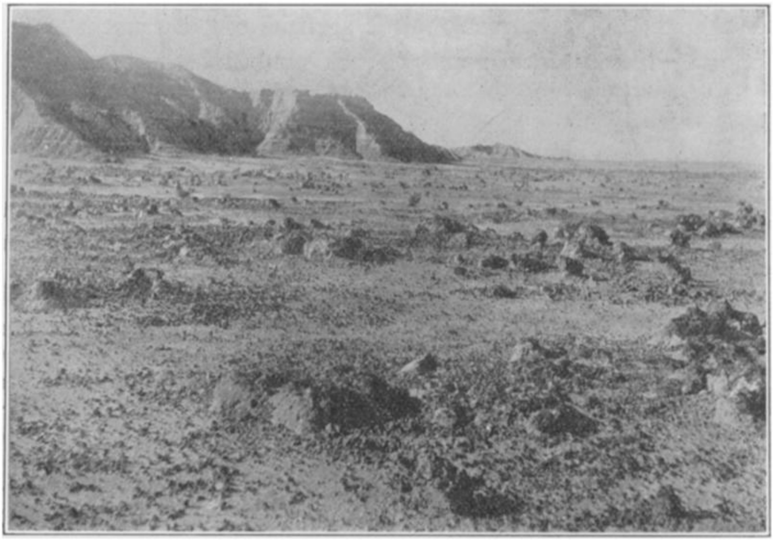

FIG. 1.

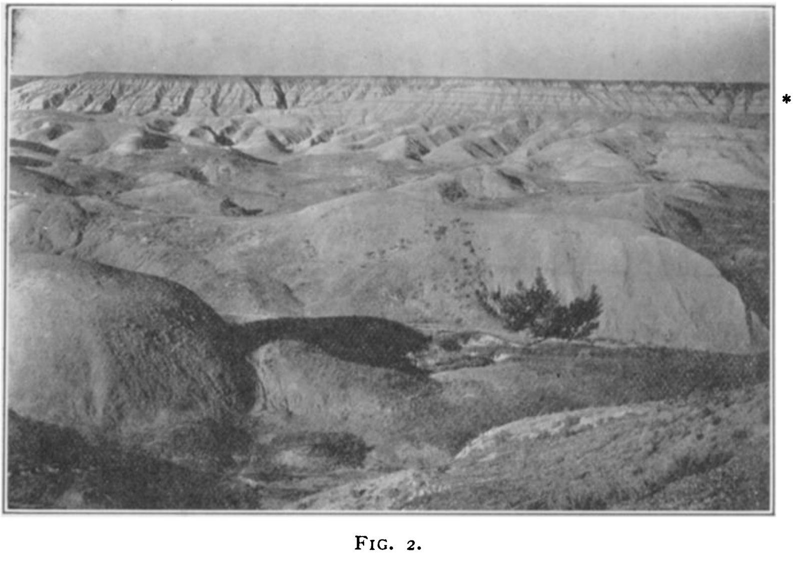

FIG. 2.

Oreodon beds capping flat-topped buttes south of the town of Scenic and abounding in the tests of ostracod crustaceans, even in completely silicified portions of the rock, they are interpreted as deposits formed in shallow pools on the surface of the level plain on which the Oreodon beds were later deposited, as discussed below. Some have been completely replaced by silica, showing white or brown chert bands. Titanothere bones in place have been seen at several localities but a few feet below these white lenses. Above, the "red layer" is usually overlain by a zone of greenish nodules and sandy lenses in a green clay about 17 feet thick where measured in the eastern part of the basin of Indian Creek. The difference in lithology and color and the extreme poverty in fossils of this green noduliferous zone, in striking contrast with their abundance but a foot or so below, makes the identification of the upper limit of the horizon in question an easy matter, and the collector is always eager to return to it after his excursion into the barren layer above.

In Pennington County the "turtle-oreodon layer" is usually a harsh-feeling pinkish-gray clay with greenish banding and mottling, containing in the uppermost six or seven feet one or more zones of calcareous concretions (Pl. VII., Fig. 1), frequently inclosing turtles or *Oreodon* and other skulls and partial skeletons. The pinkish tinge is much more apparent when the beds are wet after a rain. They abound in rolled clay pellets best seen in the nodules which are merely local hardenings of the clay without concentric structure. Possibly the inclosed fossils have at times controlled the accretion of calcareous material, but very many contain no fossils nor any visible central nucleus. They vary in diameter from a fraction of an inch to several feet. Their surface may be stained a rusty brown and is pitted with depressions left by the weathering out of the clay pellets just referred to. Sometimes a calcified root tracery is visible on the surface of a concretion. Occasionally, as observed at several places in the basin of Indian Creek, they fuse into a solid sheet of rusty, clayey limestone a few inches to a foot or more thick, from which fossils are absent, but with return to the condition of separate nodules fossils reappear.

In Pennington County the nodules are locally cut out, either altogether or in part, by channels of varying depth filled with coarse greenish micaceous sandstone, which I take to be the equivalent of the Metamynodon channel sandstone, as they occupy a position similar to the latter. The nodules do not pass through the sandstones or lie above them, but stop suddenly at the edges of the channels and reappear beyond them, which can only be interpreted as erosion subsequent to the deposition of the nodular zone; but there are other channels clearly contemporary with the "turtle-oreodon layer" and wholly inclosed within it as observed to the east of Chamberlain Pass, about 4.5 miles east of Scenic in the basin of Cain Creek, where the lower levels of the "turtle-oreodon layer" may be diversified by zones of pale green lime-cemented concretions or hard greenish sandy clays cut by vertical joints into spherically weathering blocks and separated horizontally by beds of soft clay. Furthermore, a well-defined green sandstone channel was here noted in the upper part of the "red layer" itself.

In Jackson County, in the vicinity of Cedar Pass near Interior, along the south side of "The Wall," the contact of the "turtle-oreodon layer" with the Titanotherium beds is somewhat doubtful owing to the presence in both of greenish nodular zones which look very much alike and to the local absence of fossils characteristic of the Titanotherium beds. My measurements started somewhat arbitrarily at the top of a rather persistent bed of reddish clay above which an Oreodon beds fauna occurs throughout a zone of reddish and greenish banded clays 43 feet, more or less, thick with frequent bands of nodules, greenish in color in the lower part and, at the top, rusty and cellular, inclosing fossils and similar in every respect to those described from the Big Badlands. At the Cedar Pass locality the "turtle-oreodon layer" is followed by 58 feet, more or less, of clay from which nodules are conspicuously absent, faintly color-banded (red and green) and practically free from coarse material except an occasional thin lens of sandstone. It will be noted that this sequence of beds is somewhat different from that found 40 miles or more farther west, but this is not an infrequent occurrence in Tertiary continental formations. The remarkable thing is the presence of the "turtle-oreodon layer" or "red layer" over such a vast extent of country, with everywhere the persistence of a rusty nodular zone at its top, and its development over what appears to have been a base-leveled surface (Fig. 2, Pl. VII.).

Before discussing the origin of the "red layer" a novel feature should be mentioned, namely, the presence at several horizons in the upper Titanotherium and lower Oreodon beds in the basin of Indian Creek of calcareous crusts and nodules formed by the functioning of blue-green algæ, similar to the algal balls described by Professor H. Justin Roddy from Little Conestoga Creek, Lancaster County, Pennsylvania.[1] One of these algal reefs occurs in the upper part of the "turtle-oreodon layer," probably in Sec. 6, T. 4 S., R. 13 E., Black Hills Mer., in the most easterly part of Indian Creek basin about half a mile west of the narrow mesa known locally as Hart Mountain. It is exposed along the south side of a minor badland draw and occurs both in the pinkish-gray clays of the "turtle-oreodon layer" and along the margin of a channel-filling of green micaceous sandstone interrupting the upper part of the brown nodular zone. Laterally, the reef passes into the sandstone, some of the algal masses rising as miniature islands through the sand. Most of the algal growth here is in the form of a crust, only a foot or so of its width remaining in place, the rest being scattered as talus blocks over the underlying clays. At least three zones of rusty nodules are present in the general vicinity of this reef. The nodules decrease in number as the south edge of the algal crust is approached and almost disappear. The reef first appears as a thin seam in the pinkish-gray clays and rapidly thickens up to a maximum of two inches or so of typically concentrically-banded, *Stromatopora*-like algal crust and balls. About 50 feet north of the south edge of the algal crust it abuts on the green channel sandstone already mentioned. The whole deposit has a length from north to south of 225–250 paces and is scattered as talus over a width of clay slope from 25 to 50 feet beyond its outcrop. Rusty nodules of the type inclosing rolled mud pellets are much less abundant throughout the area occupied by the algal reef, because cut out by the channel with which it is associated. A few project from their clay matrix below the level of the algal crust; none were seen included in it. These algæ grew at the edge and partly within a shallow stream cutting the "turtle-oreodon layer". Elsewhere throughout Indian Creek basin algal crusts and balls have been seen at several localities in the upper part of the Titanotherium beds, not far below the Oreodon beds contact, resting on a clay substratum and sometimes growing over bone fragments. Specimens of both types have been sectioned and the material submitted to Dr. Marshall A. Howe, of the New York Botanical Garden. His studies thereon have been most seriously handicapped by recrystallization of the organically formed limestone, almost completely obliterating the original cellular structure. Dr. Howe thinks that one organism dominates, and that there is no very serious admixture, and, furthermore, that "it is most reasonable to suppose that the plant belongs with the Myxophyceæ (Cyanophyceæ or Blue-green Algæ), and under this class its family is most likely to be the Rivulariaceæ, though one can not feel absolutely confident of it. One would not be justified in referring it to any known genus, living or fossil, and there is nothing very definite, concrete, or detailed on which to establish a new genus."

---

[1] Proc. Am. Phil. Soc., Vol. LIV., 1915, pp. 246–258, two figures.

In formulating a theory of origin for the "turtle-oreodon layer" conditions controlling the deposition and preservation of the numerous fossils, as well as lithologic and stratigraphic data, must be considered. Every collector is at once struck by the enormous numbers of fossil turtles of all sizes. These are not aquatic forms, but, as Dr. Hay[2] has pointed out, are closely related to our living land tortoises, so far as can be determined from the material available, mostly empty carapaces. These, quite irrespective of size, do not lie in death pose, but may be upside down or on edge. Heads and limbs are missing and have either been eaten by carnivores or decayed and dropped off when the shells were moved by the transporting agent. The majority of the other fossils found are mammalian skulls, often with lower jaws attached, and lie in all sorts of positions. Loosely inserted teeth are sometimes missing, but there is little or no indication of abrasion by movement in material found outside the sandstone channels. Many of the skulls were reduced before interment to the condition of tooth-bearing jaw-fragments, the portion of the body most resistant to decay. Turtle shells and all the cavities in the skulls are completely filled with a harsh-feeling pinkish-gray[3] clay full of small rolled clay pellets. These are not concentrated into lenses, but evenly distributed throughout the clay. Mouse-nibbled bones and abundant undissolved coprolites of carnivores are common features in the same matrix with the skulls and turtle shells. One associated *Oreodon* skeleton collected by the Princeton Expedition of 1920 had the head and neck bent back in a manner frequently observable in the more or less dried-up carcasses of sheep killed by winter storms. A film of iron oxide, red or yellow, frequently covers the fossil bones, their organic content perhaps acting as a precipitant on iron compounds which subsequently oxidized. Some of the original calcareous material of the bones still remains, but much has been replaced by silica, which may completely fill marrow cavities in limb bones, and pulp canals in teeth, and occurs also in the form of chalcedony veins in the numerous shrinkage cracks which traverse both Titanotherium and Oreodon beds.

---

[2] O. P. Hay, "The Fossil Turtles of North America," Carnegie Institution of Washington. Publication No. 75, p. 385, 1908.

Turning now to stratigraphic and lithologic data, in the basin of Indian Creek, when viewed from a distance, the Chadron-Brule contact is seen to be remarkably even and free from sinuosities, apparently a base-leveled erosion plane separating the soft cross-bedded clays and channel sandstones of the Titanotherium beds, with their smooth hummocky hill profiles, from the horizontally stratified, evenly color-banded, harsh-feeling Oreodon clays with their dendritic type of dissection and steeper slopes. The sudden disappearance of titanotheres at the contact is further proof of a stratigraphic break. When examined close at hand, the contact loses much of its distinctness, owing to the softness and similarity of materials on either side of the erosion plane. Over this surface, on which were numerous minor ponds floored with marl (the silicified limestones already described as occurring at the contact), a harsh pinkish-gray clay full of rolled clay pellets was laid down in layers, apparently at times when the plain was inundated by successive, perhaps very shallow and temporary, floods, a conclusion similar to that reached years ago by Hatcher.[4] The spreading of such floods would account for the distribution of rolled clay pellets, the overturning of the shells of dead land turtles, the drowning of others in vast numbers and perhaps the suspension of their gas-distended bodies long enough for decomposition to separate the heads and limbs, for the covering of sun-dried shrunken carcasses· and such bones as may have lain on the surface and for the filling of all the cavities in the skulls and turtle shells with fine mud. That such flooding was temporary may be inferred from the widely distributed carnivore excrements, perhaps coated with a film of clay, but still bearing sharp impress of the sphincter ani muscles and certainly not voided in water.

---

[3] The color is about intermediate between "seashell pink" and "pale ochreous-salmon" of Ridgway's Color Standards and Nomenclature, Pls. XIV., XV., 1912, with a pale gray tone and has accordingly been spoken of above as pinkish-gray.

The brown rusty nodules have, I think, been produced by the rise surfaceward, through capillarity in time of drought, of subsurface waters charged with carbonate of lime and the deposition of this limey content through evaporation, locally cementing the clays along definite planes parallel to the surface of the ground, forming either solid sheets or bands of nodules, depending, perhaps, on the amount of lime present, the quantity of water being evaporated, or both. Occasionally bones acted as centers of accretion. The rusty stain is a phenomenon confined to the surface of the nodules and was probably produced subsequent to their exposure by weathering. It is not always developed, and the nodules may be similar in color to the investing clays.

The origin of the sediments of the "turtle-oreodon layer" is part of a larger problem involving the source of the materials of the White River Oligocene as a whole, consideration of which is deferred until a later occasion. The harshness of feel which characterizes both clays and sandstones is largely due to calcareous impregnation, for, strange to say, while the fossils are in part silicified and there is abundant chalcedony in the veins which traverse the clays, the cementing substance of the rusty fossiliferous nodules and of the soft channel sandstones is carbonate of lime and not silica. Only rarely does the matrix of a fossil or the immediate vicinity of a large chalcedony vein show siliceous impregnation. When the calcareous cement of the channel sandstones associated with the "turtle-oreodon layer" is dissolved in hydrochloric acid, the insoluble residues are found to abound in quartz grains, foils of white mica, clay pellets and fine clay dust, and very finely divided pinkish clay with minute quartz fragments constitutes the matrix of the "red layer" itself. While I have found abundant volcanic ash in one of the higher horizons of the Oligocene, I have not established its presence in the "turtle-oreodon layer," although it is perfectly possible that it occurs mixed with the pinkish clays and perhaps may have supplied the silica which replaces fossils and fresh-water limestones and occurs in such abundance in the chalcedony veins. The latter are posterior in origin to the caliche nodules in the upper part of the "red layer," since fossils and nodules are frequently cut by them. Rosettes and geodes are other forms assumed by the same material.

---

[4] J. B. Hatcher, "Origin of the Oligocene and Miocene Deposits of the Great Plains," PROC. AM. PHIL. SOC., Vol. XLI., pp. 113–131, April, 1902.

I am of the opinion that a climatic factor is involved in the problem of the origin of the White River sediments, but, at the present stage of the investigation, am not prepared to demonstrate it fully. Certain facts observed in connection with the horizon we have been discussing seem to bear on the subject. In the valley of Indian Creek the Titanotherium beds rest with marked unconformity on the eroded surface of the Pierre shale, with a basal conglomerate at the contact containing pebbles of quartz, chert and other hard rocks. The top of the substratum has considerable topographic relief, so that the thickness of the Titanotherium beds varies from place to place. Throughout this formation cross-bedding is common and there are frequent large channels filled with coarse quartzose sediments. The impression conveyed is that of fluviatile deposition under conditions of generous rainfall, abundant run-off and rapid sedimentation. Accumulation of detritus eventually ceased, temporarily, and erosion began, producing the base-leveled surface which separates the Titanotherium from the Oreodon beds, an event which I would associate with a climatic rhythm, perhaps a swing toward dryer conditions, bringing about the extinction of *Titanotherium.*

With the return of fluviatile deposition, a slower accumulation of silt by sheet-flood action over a level plain may be indicated by the predominance of approximate horizontality in the stratification and uniformity in the thickness of the color-banding. The slight southeasterly dip which the beds show (Plate VII, Fig. 2), inclining them at a greater angle than the present high-prairie top, is probably initial dip, possibly intensified by subsequent warping. Seasons or cycles of less abundant precipitation, during which ground water was drawn surfaceward by capillarity, are indicated by the zones of caliche nodules. Perhaps the pink color of the basal clays of the Oreodon beds, the "turtle-oreodon layer" or "red layer" we have been discussing, has a climatic significance, but considering how little we know about the chemical changes involved in the iron compounds responsible for the color or the conditions under which they take place, it would be unsafe to conclude that it indicated aridity, for our modern western-desert sediments are gray and not red. Certain pink clay zones farther up in the Oreodon beds, shown as darker bands in the distance in Fig. 2, perhaps owe their color to climate, but what kind of climate must remain, for the present, doubtful. The testimony of mouse-nibbled bones, carnivore excrements and carcasses in death pose fits in with the climatic rhythm here suggested.

The zone of green channel-sandstone lenses weathering into spherical concretions, which occurs above the basal pinkish-gray clays of the Oreodon beds in the Big Badlands, may represent a swing-back toward the pluvial cycle. Minor rhythms are, I think, indicated by certain of the larger channel fillings, such as the Metamynodon channels, filled with coarse sediments and affording remains of an aquatic rhinoceros. These may have been deposited during cycles of greater precipitation about the headwaters of the streams, which sent them, charged with coarse sediments, far out over the clay-covered plain to the east.

The recurrence of *Metamynodon* in channels at different levels, noted by Wortman,[5] fits in with the interpretation just suggested, for with every spreading eastward of the streams, due to climatic causes, the fauna living along the water courses would recur in the channels cutting the clays in which we find remains of the animals of the plain. So far as my observations have gone, these channels are posterior to the formation of the caliche nodules and not contemporary with them, since they cut out the nodular zones.

---

[5] *Bull. Am. Mus.,* Vol. V., Article IX., p. 101, 1893.

That these changes did not involve a lowering of temperature is suggested by the presence of alligator-like forms, few in numbers, but occurring, nevertheless, in the Titanotherium beds.[6] They persist in the higher plains area until Pliocene time, as shown by the discovery of a single crocodilian vertebra in the Snake Creek Pliocene gravels in Sioux County, northwestern Nebraska, by our 1914 expedition.[7] I have not yet identified any volcanic ash in the "red layer," nor have I noted therein any sediments which might be regarded as of æolian origin.

Plate VII.

Fig. 1. Rusty concretions and turtles weathering out of the "turtle-oreodon layer" which covers the flat in the foreground. Princeton collecting locality 1015D2a on the west side of the Reservation road, 5.1 miles south of Scenic, Pennington County, South Dakota. Looking north. This locality is near the divide between Cheyenne R. and White R. drainage in the Bear Creek basin. Typical exposure at a highly fossiliferous locality.

Fig. 2. Contact, indicated by the asterisk, between the Titanotherium beds (foreground) and the banded Oreodon beds (background) on the west side of Hart Table, valley of Indian Creek, Pennington County, South Dakota. Looking east. The slight southeasterly dip of the Oreodon beds is also shown. Princeton collecting locality 1015A 1.

---

[6] F. B. Loomis, "Two New River Reptiles from the Titanothere Beds," *Am. Jour. Sci.*, 4th Series, Vol. 18, pp. 427–432, 1904. M. G. Mehl, "Caimanoidea Visheri, a New Crocodilian from the Oligocene of South Dakota," *Jour. of Geol.*, Vol. XXIV., No. 1, Jan.–Feb., 1916, pp. 47–56.

[7] Proc. Am. Phil. Soc., Vol. LIV., No. 217, May–June, 1915, p. 77.